REGENERATION OF HEATH AND HEATH WOODLAND IN THE NORTH-EASTERN OTWAY RANGES THREE TO TEN YEARS AFTER THE WILDFIRE OF FEBRUARY 1983

MARGARET C. WARK

Angair Incorporated (Anglesea and Aireys Inlet Society for the Protection of Flora and Fauna), PO Box 12, Anglesea, Victoria 3230

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Studies of the post-fire regeneration of the heath, tall shrubland, scrub and heath woodland communities in the Anglesea district, 3–10 years after the wildfire of 1983, show that maximum post-fire species richness of vascular plants occurred in the early years after fire, and that no additional species appeared between 3 and 10 years post-fire. Vascular plant species richness decreased with time since fire, and by year 10 was 60% of that in years 1–3. Approximately 40% herbaceous species and 80% shrub species present immediately post-fire were still present at year 10. In contrast, the species richness of non-vascular plants increased almost four-fold with time since fire. Twenty-nine additional species appeared between 3 and 10 years as canopy and understorey cover increased.

In the heath woodlands, the eucalypt canopy reached approximate pre-fire height and projective cover levels by 7 years. Recovery of the heathy substratum slowed as canopy cover increased between 3 and 10 years. Over 70% of the understorey species which remained at year 10 had the capacity to regenerate vegetatively after fire. In areas not affected by *Phytophthora cinnamomi*, sclerophyllous shrubs were the main component of the understorey at year 10.

THE north-eastern Otway Ranges, Victoria, is a species-rich region of south-eastern Australia containing extensive areas of fire-prone dry sclerophyll forest and heath woodland (Beauglehole et al. 1977; Parsons et al. 1977; Carr & Robinson 1985; Meredith 1986; Australian Heritage Commission 1993). Until 1983 there had been no published study of the fire ecology of the flora and fauna of this region. Following the wildfire of Ash Wednesday (17 February 1983) in which almost 40 000 ha of vegetation near Anglesea and Airey's Inlet were burnt, a ten year study of post-fire recovery of vegetation and fauna was initiated. This multidisciplinary project involved groups from Angair, Deakin University, the Royal Australian Ornithological Union and the Museum of Victoria, who monitored recovery in six of the major plant communities in the district (coastal heath, heath woodland, ironbark open-forest, sand dune scrub, swamp thicket and fern gully).

The aims of the botanical study were to monitor vegetation recovery following wildfire, and to provide information for use in conservation management.

Data on early stages of regeneration of coastal heath and heath woodland communities have been published (Wark et al. 1987), and key findings were:

1. *Species re-establishment*
   Ninety per cent of all species present before the fire reappeared within the first year. All other species reappeared by year 2.

2. *Regeneration strategies*
   Thirty-seven per cent of species were obligate regrowth regenerators, 30% facultative regrowth regenerators, and 33% obligate seed regenerators.

3. *Structure recovery*
   Rate of recovery of canopy height in heath woodlands (in years 1–3 post-fire) was faster than rate of recovery of canopy projective cover.

4. *Flowering response*
   Fifty-two per cent of species flowered in the first year after fire, and 98% had flowered by the end of the third year.

   Most of the species which flowered in the first year were herbaceous, and included members of the Liliaceae, Orchidaceae, Droseraceae, Asteraceae and Poaceae.

   The early 'herbaceous phase' declined in cover and density of flowering during the second and third years as shrub and canopy cover increased. Grazing by native and introduced mammals reduced frequency and density of herbaceous species in the early years after fire.

5. *Seeding response*
Though most shrubs commenced flowering within two years of fire, few had produced seed by year 3.

This present paper reports data collected in coastal heath and heath woodland 3 to 10 years after fire and examines changes which have occurred during this time. Mammal, bird and insect data have been reported separately (Wilson & Moloney 1985a, 1985b; Reilly 1985, 1991; Andersen 1987).

SITE DESCRIPTIONS

The three study sites (A, B and C) each contained several plant communities ranging from coastal closed heath (dominated by *Banksia marginata*, *Allocasuarina pusilla* and *Leptospermum myrsinoides*) to heath woodland dominated by *Eucalyptus obliqua*. They have already been described in detail (Wark et al. 1987, fig. 1, table 1) and will be referred to in the present paper as plant subcommunities at subsites. In this paper the general term 'heath woodland' will include the physiognomic types open scrub, tall shrubland and woodland. The fire history of every site differed. Site A was crown fired by wildfires in 1958 and 1983; site B was control burnt in 1973, and crown scorched by wildfire in 1983; and site C was crown fired by wildfires in 1969 and 1983 (P. Denham, pers. comm.; Cecil 1993a, 1993b).

Site C was near an operating open cut brown coal mine. Unfortunately this site was destroyed by mining operations which commenced six years post-fire. However, sites A and B remained undisturbed and data collected at these two sites up to 10 years post-fire are presented below.

Because of the extent of the Ash Wednesday wildfire (Wark et al. 1987, fig. 1), no unburnt sites comparable to sites A, B and C existed for comparison.

METHODS

Vegetation

Pre-fire data. Detailed species lists existed for vascular plants for each site prior to the 1983 fire (White 1982). However no quantitative data on pre-fire floristics or vegetation structure were available. Approximate pre-fire height was interpreted from pre-fire photographs and the height of burnt tips. Approximate pre-fire projective cover was also estimated from pre-fire field observations and photographs.

Data collection and data analysis. For methods see Wark et al. (1987). Data were collected in spring, 3, 7 and 10 years after fire. Total species lists were made for each site and subsite at each survey, and this information used to supplement quadrat data on floristics, flowering and regeneration strategies. As in the previous paper (Wark et al. 1987), the term 'total number of species' at a site (or subsite) refers to the total number of species recorded in the quadrats *plus* any additional species recorded at that site (or subsite). In the present paper, quadrat data alone is used to analyse the relationship between plant species richness and total vascular plant cover.

Nomenclature of most plants follows Ross (1993); for *Danthonia* now *Rytidosperma* – N. Walsh, pers. comm.; for mosses – Scott & Stone (1976); liverworts – Scott (1985); lichens – Filson & Rogers (1976); and orchids – Backhouse & Jeanes (1995). Name changes of vascular plants which have occurred since the earlier paper (Wark et al. 1987) are presented in the Appendix. In addition, three species of plants were incorrectly identified in Wark et al. (1987), and will be referred to by their correct names in the present paper. They are the liverwort *Marchantia polymorpha* now known to be *Marchantia berteroana* (Scott, 1985); the fungus *Omphalia chromacea* now known to be *Gerronema postii* (May & Fuhrer, 1989); and the herb *Viola hederaceae* ssp. *sieberiana* now known to be *Viola cleistogamoides*. Species of the moss *Campylopus* (especially *C. clavatus* and *C. pyriformis*) are very hard to discriminate when young, and misidentifications are to be expected.

Regeneration strategies terminology. Terminology follows Purdie (1977a, 1977b), namely: OSR = obligate seed regenerator (regenerating from seed or propagates only); FRR = facultative regrowth regenerator (regenerating by regrowth, and from seed or propagules); ORR = obligate regrowth regenerator (regenerating by regrowth only).

Other methods

Rainfall. Rainfall data for Anglesea (for years 1986–1989 inclusive) were obtained from the Bureau of Meteorology. No records were kept at Anglesea for 1990–1992, so rainfall figures for these years are unofficial (courtesy the late P. F. Marriott).

Soil pathogens. Samples of soil 10 × 10 × 10 cm taken (in October 1985) near dying plants of *Isopogon ceratophyllus* R.Br. and *Xanthorrhoea australis* R.Br. (approx. three years after fire) were tested for the presence of *Phytophthora cinnamomi* Rand by Dr G. C. Marks (Department of Conservation & Natural Resources) using a cotyledon baiting technique (Marks & Kassaby 1974).

Field observations for the continued presence of *P. cinnamomi* continued to year 10. Dying plants of *I. ceratophyllus* and *X. australis* were used to indicate the presence of *P. cinnamomi* throughout the study to year 10 (Weste & Taylor 1971; Weste & Law 1973). Sites where *P. cinnamomi* may have killed *X. australis* in the pre-fire period were indicated by the presence of burnt out stem bases of *X. australis.*

RESULTS

Soils

Moisture. Field observations between years 3 and 10 confirmed the previous observations of seasonal water logging in depressions and shallow slopes during winter (June–August). Total rainfalls for Anglesea (annual mean 657 mm) for the years 1986 to 1992 inclusive were 622, 740, 643, 825, 596, 614 and 758 mm respectively.

Soil pathogens. *Phytophthora cinnamomi* Rands was isolated from soil and root samples taken from dying plants of *I. ceratophyllus* and *X. australis* at four of the six subsites (A_2, B_1, B_2 and B_3) approximately three years post-fire. Signs of dieback due to *P. cinnamomi*, as shown by indicator species, occurred in patches as a mosaic at all subsites in the 10 years post-fire.

At four of the six subsites (A_2, B_1, B_2 and B_3) the presence of burnt out bases of *X. australis* indicated that the pathogen may have been present before the fire occurred. Such indications of pre-existing *P. cinnamomi* disease were seen upslope of, and adjacent to, all of the subsites at site B. These probable areas of infection contained few sclerophyllous shrubs and the understorey which regenerated in the ten years following the fire was sparse and open and composed mainly of sedges and rushes such as *Gahnia radula*, *Lepidosperma semiteres* and *Lepidosperma filiforme*. Dying and dead sclerophyllous shrubs and *X. australis* appeared in the heathy understorey down slope from these areas in the ten years following the fire.

Vegetation

Floristics. The floristics of the plant sub-communities one, three and ten years post-fire are presented as presence–absence data in Table 1 (data collected in year 7 have not been included but are available from Angair). Two hundred and twenty-one species of vascular plants appeared by 3 years post-fire and no additional vascular plant species between 3 and 10 years. In contrast, 10 species of non-vascular plants appeared by year 3 and an additional 29 non-vascular plant species between years 3 and 10.

A total of 6 tree species, 63 shrubs, 141 species of herbs, 5 creepers and climbers, 6 ferns and 39 species of non-vascular plants were present, giving a total species list of 260 for the ten years post-fire at sites A and B (Table 1). In this paper the term graminoid will not be used, and the term herb will be used to mean an herbaceous species (Table 3).

Total plant species richness (quadrat and site data combined) ranged from 86–159 per sub-community (Table 1), and from 42–86 at year 10 post-fire (Table 1); a reduction of approximately 40% when compared with years 1 and 3 combined (78–137 species; Table 1).

The total number of species present 10 years post-fire was also approximately 60% of the year 1 and 3 level (Table 3). The number of herbaceous species present decreased by year 10 to about 40% of the year 1–3 level (Table 3).

Only 22% of species of Poaceae, 42% of lilies and irises, and 50% of Orchidaceae seen 1–3 years post-fire were recorded at year 10. However, 60% of species of sedges and rushes present at year 1 were still seen at year 10. In contrast, 80% of species of shrubs seen at years 1–3 were still recorded at year 10 (Table 3). Ten shrub species were present at all subsites at years 1, 3, 7 and 10. They were *Acrotriche serrulata*, *Epacris impressa*, *Leucopogon virgatus*, *Monotoca scoparia*, *Platylobium obtusangulum*, *Leptospermum myrsinoides*, *Banksia marginata*, *Isopogon ceratophyllus*, *Pimelea humilis* and *Tetratheca ciliata*.

Though non-vascular plants were uncommon, the number of species present increased three and a half-fold by year 10, compared with years 1 and 3 (Tables 1, 3; 10 species years 1–3, 35 species year 10). The early colonisers (*Funaria hygrometrica*, *Marchantia berteroana*) which appeared at year 1, were not seen after year 3. Seven additional species of bryophytes appeared between years 2 and 3, and an additional 29 species after year 3. Between years 3 and 10 post-fire, the

Site	A			B		
Subsite / Vegetation formation	A_1 Closed heath	A_2 Open scrub	A_3 Tall shrubland	B_1 Woodland	B_2 Woodland	B_3 Woodland/ closed scrub
Trees*						
Myrtaceae						
Eucalyptus aromaphloia			(1) (3)(10)			
Eucalyptus baxteri		1 3 10	(1)			
Eucalyptus obliqua	(1) (3)(10)	1 3 10	1 3 10	1 3 10	3 (10)	1 3 10
Eucalyptus tricarpa		1 3 (10)	(1)			
Eucalyptus viminalis				(1) (3)(10)		
Eucalyptus willisii				(1) (3)(10)	(1) (3)(10)	(1) (3)(10)
Tall shrubs*						
Casuarinaceae						
Allocasuarina verticillata	1 3 10		1 3 10			
Mimosaceae						
Acacia pycnantha		1 3 10	(1) (3)(10)			
Acacia verticillata						1 3 10
Algae**						
Nostoc spp.	10	10				
Lichens**						
Cladia aggregata	3 10	3 10	10	10	10	10
Cladia schizopora	10					
Cladonia cervicornis ssp.			(10)	10		10
Cladonia chlorophaea	3	3		10		
Cladonia corniculata			(10)	10	10	
Cladonia praetermissa		10				
Cladonia ? merochlorophaea		10				
Cladonia enantia	10					10
Cladonia spp.	10	10	10		10	
Parmelia spp.	10					
Ramalina spp.	10		10			
Teloschistes spp.	10					
Thysanothecium scutellatum						10
Usnea ? inermis	10					10
Unidentified spp.		3 10	10			
Liverworts**						
Cephaloziella exiliflora		(10)				
Chaetophyllopsis whiteleggei	(10)	10				
Enigmella thallina	10	(10)	10			
Fossombronia ? intestinalis	(10)					
Goebelobryum unguiculatum		10			3 10	10
Hyalolepidozea longiscypha		10				
Kurzia compacta					10	10
Lophocolea semiteres	(10)					
Lethocolea pansa	10	(10)	10			
Marchantia berteroana		1 3				
Riccardia aequicellularis	(10)					
Fungi**						
Gerronema postii	1				(3)	

Table 1 continued next page (see legend on page 131)

Site	A			B		
Subsite Vegetation formation	A_1 Closed heath	A_2 Open scrub	A_3 Tall shrubland	B_1 Woodland	B_2 Woodland	B_3 Woodland/ closed scrub
Mosses**						
Barbula calycina	3 (10)	3 10		10	3	
Bryum argenteum		10				
Bryum billardieri	(10)				10	
Bryum pachytheca	3					
Campylopus australis					10	
Campylopus clavatus	10	10	10			
Campylopus introflexus	3 10	10	10	10	3 10	3 10
Ceratodon purpureus	3	3 (10)	3		3	3
Funaria hygrometrica	3	1 3	3		3	3
Funaria bullata	(10)		(10)			
Polytrichum commune	10					
Polytrichum juniperinum		10				10
Tayloria octoblepharis	10	(10)				
Unidentified spp.	3 10	3	3 10	3	3	3
Ferns and allies**						
Lindsaeaceae						
Lindsaea linearis		(3)			(3)	
Schizaeaceae						
Schizaea bifida					(3)	
Schizaea fistulosa						(1) (3)
Selaginellaceae						
Selaginella uliginosa						(1) 3 10
Centrolepidaceae						
Centrolepis aristata	1 3 10		1			
Centrolepis strigosa		(3)		(1) (3)		
Sedges and rushes**						
Cyperaceae						
Baumea acuta						(1) (3)(10)
Caustis flexuosa					(3)	
•*Cyperus tenellus*	(1) (3)				(3)	
Gahnia radula	(1) (3)(10)	1 3 10	(1) (3) 10	1 3 10	1 3 10	1 3 10
Isolepis inundata	1					
•*Isolepis marginata*	1					
Lepidosperma concavum	1 3 10	1 3 10	1 3 10			
Lepidosperma filiforme				10		
Lepidosperma semiteres	1 3 10	1 3 10	1 3 10	1 3 10	(3)	
Schoenus apogon	1 3	1 3	1 3		(3)	
Schoenus breviculmis	1 3 10	1 3 10	1 3 10	(1) (3)		
Schoenus brevifolius						(1) (3)(10)
Schoenus tenuisimus					1 3 10	1 3 10
Juncaceae						
Juncus pauciflorus		(3)				
Juncus planifolius						(1) (3)
Restionaceae						
Empodisma minus						1 3 10
Hypolaena fastigiata				(3)	1 3 10	1 3 10
Unidentified sedge/rush						10

Table 1 continued next page *(see legend on page 131)*

Site	A			B		
Subsite / Vegetation formation	A_1 Closed heath	A_2 Open scrub	A_3 Tall shrubland	B_1 Woodland	B_2 Woodland	B_3 Woodland/ closed scrub
Grasses**						
Poaceae						
•*Aira caryophyllea*		3				
Agrostis avenacea	(3)	(3)				
Amphipogon strictus	1 3 10	1 3 10	10			
Rytidosperma caespitosum		(1)				
Rytidosperma geniculatum	(3)	(3)	1 (3)			
Rytidosperma indutum	1	1	1	(1)	(1)	
Rytidosperma pilosum		(1)	1			
Rytidosperma procerum		(1)				
Rytidosperma semiannularis		(1)				
Rytidosperma setaceum	1 3 10	1 3 10	1 3 10	1 3 10	(1)	(1)
Rytidosperma tenuis		(1)				
Deyeuxia densa						(1)
Deyeuxia quadriseta		(1)	(1)	1		(1)
Dichelachne crinita	(1)	(1)				
Dichelachne rara						(1)
•*Holcus lanatus*	(1)	(1)				
Microlaena stipoides	(1)	(1)		(1)		
Poa morrisii						1 3 (10)
Poa sieberiana		1 3 10				
Stipa semibarbata	1 3 10	1 3 10	1 3 10	1 3 10	(1)	
Tetrarrhena distichophylla		(1) (3)				
Themeda triandra		(1)				
•*Vulpia myuros*		1 3				
Unidentified grasses	1 3 10	1 3 10	1 10	1 3		1 10
Orchids**						
Orchidaceae						
Acianthus caudatus	(1)	1 (3)(10)	1 (3)		(1)	
Acianthus pusillus	1 (3)	3 (10)	3 10		(1)	
Caladenia cardiochila	(1)	1 (3)(10)		1	(1)	
Caladenia carnea	(1)				(1)	
Caladenia deformis	(1)				(1)	
Caladenia tentaculata	1 (3)	(10)	3	1 3	(1)	
Caladenia pusilla	1 3				(1)	
Caladenia spp.		(10)				(10)
Calaena major				(1)	(1) 3	
Calochilus campestris					(1)	(1)
Calochilus robertsonii					(1)	(1)
Chiloglottis reflexa					(3)	
Cyrtostylis reniformis		(3)	(3)		(1)	
Diuris corymbosa	1 (3) 10	(3)	(3)	1 (3)	(1)	
Eriochilus cucullatus	(1)				1	1 3
Glossodia major	(1) (3)	1 3 (10)		1 (3)	1 (3)	1 3
Leptocerus menziesii	(1) (3)				(1)	(1) (3)(10)
Microtis parviflora	(1)	(10)	1			
Microtis uniflora	1	(1)				
Orthoceras strictum	(1)		1	(1)	(1)	

Table 1 continued next page (see legend on page 131)

Site	A			B		
Subsite	A_1	A_2	A_3	B_1	B_2	B_3
Vegetation formation	Closed heath	Open scrub	Tall shrubland	Woodland	Woodland	Woodland/ closed scrub
Orchids** *(continued)*						
Orchidaceae *(continued)*						
Genoplesium despectans					(1)	
Prasophyllum elatum					(1)	
Genoplesium morrisii	1 (3)	(3)(10)	1 (3)		(1)	
Prasophyllum odoratum	1				(1)	
Pterostylis longifolia	(1)	(1) (3)	10		(1)	
Pterostylis nana	(3)	(3)	1 (10)		(1)	
Pterostylis nutans		(1)				
Pterostylis parviflora	1 (3)	(3)	1	1 10	(1)	
Pterostylis plumosa	1 (3)	(10)	3 10	3 10		
Pterostylis sanguinea		(10)				
Pyrorchis nigricans				1 3 10	1 3	
Thelymitra antennifera	1 3 (10)	3 10	3 10	1 (3) 10	1	(3)
Thelymitra flexuosa	(3)		3	(1)		
Thelymitra benthamiana	(1) (3)		(1) (3)(10)			
Thelymitra ixioides	(3)	3	1	(1)	(1)	
Thelymitra pauciflora	1	10		1 3	(1)	
Thelymitra rubra	1 (3)			(3)	(1)	3
Thelymitra spp.	1 3 (10)	3 (10)	1 3	1 10		(10)
Lilies and irises**						
Liliaceae						
Burchardia umbellata	1 3 10	1 3 10	1 3 10	1	1 3 10	
Caesia parviflora	1 3					3
Chamaescilla corymbosa	1 3 10	1 10	1 10			3 10
Dianella revoluta		(1) (3)		(1) (3)	(1) (3)	
Arthropodium strictum	(1)	(1)				
Laxmannia orientalis	1 3	1 3	1 3 10	1 3 10	1 3 10	1 3 (10)
Lomandra filiformis	(1) (3)(10)	1 3	1 3 10	1 3	(1) 3 10	1 3 10
Lomandra longifolia					1 3 10	
Lomandra micrantha		(1) (3)				
Lomandra multiflora		(3)	1			10
Thysanotus juncifolius	(1) 3	(1)				
Thysanotus patersonii	1 3 (10)	1 3 10	1 3	1 3 10	1	(10)
Thysanotus tuberosus	(1)	(1)			1	
Wurmbea dioica	(1)	(1)				
Xanthorrhoeaceae						
Xanthorrhoea australis		1 3 10	10	(1) (3)(10)	1 3 10	1 3 10
Xanthorrhoea minor						(1) (3)(10)
Hypoxidaceae						
Hypoxis glabella		(1)			(1)	
Iridaceae						
Patersonia fragilis	(1) (3)	(1) (3)				1 3
Patersonia occidentalis		(1) (3)				1 3
Shrubs**						
Mimosaceae						
Acacia verticillata var. *ovoidea*						(1) (3)(10)
Acacia myrtifolia		(1) (3)(10)			(1) (3)(10)	
Acacia suaveolens				1 3 10	(1) (3)(10)	

Table 1 continued next page (see legend on page 131)

Site	A			B		
Subsite	A_1	A_2	A_3	B_1	B_2	B_3
Vegetation formation	Closed heath	Open scrub	Tall shrubland	Woodland	Woodland	Woodland/ closed scrub
Shrubs** (*continued*)						
Epacridaceae						
Acrotriche serrulata	1 3 10	(1) 3 10	(1) 3 10	1 3 10	(1) 3 10	1 3 10
Astroloma humifusum	1 3 10	10		(3)		
Brachyloma ciliatum				(1) (3)		
Epacris impressa	1 3 10	1 3 10	1 3 10	1 3 10	1 3 10	1 3 10
Lissanthe strigosa			(1) (3)			
Leucopogon australis						(1) (3)(10)
Leucopogon virgatus	1 3 10	1 3 10	1 3 10	(1) 3 10	1 3 10	(1) 3 10
Monotoca scoparia	1 3	1 3	(1) 3 (10)	(1) (3)	1 3 10	(1) 3 10
Sprengelia incarnata						1 3 (10)
Fabaceae						
Aotus ericoides					1 3 10	(1) 3
Bossiaea prostrata	3					
Daviesia brevifolia	(3)	(3)	(3)			
Dillwynia glaberrima				(1) (3) 10	1 3 10	1 3 10
Dillwynia hispida	(3)(10)	(3)(10)	1 3 10			
Dillwynia sericea	1 3 10	1 3 (10)	1 3 10	1 3		
Gompholobium ecostatum	1 3 10	1 3 10	1 3 10	1 3 10		
Hovea linearis		(3)	1 3 10	1 3 10		
Platylobium obtusangulum	1 3 10	1 3 10	1 3 10	1 3 10	(1) (3)	1 3 10
Pultenaea daphnoides		(1) (3) 10				
Pultenaea dentata			(3)			
Pultenaea gunnii					(3)	
Pultenaea humilis	(1) (3)	(1) (3)	(1) 3			
Pultenaea mollis			3			
Pultenaea stricta						(3)(10)
Sphaerolobium vimineum	3 10	(3)				3 10
Myrtaceae						
Baeckea ramosissima ssp. *prostrata*	3	(3) 10				
Leptospermum continentale	10	3 10	10	(3)(10)		1 3 10
Leptospermum myrsinoides	1 3 10	1 3 10	1 3 10	1 3 10	1 3 10	1 3 10
Melaleuca squarrosa						1 3 10
Proteaceae						
Banksia marginata	1 3 10	3 10	3 10	(1) (3)(10)	1 3 10	1 3 10
Hakea ulicina		(3)(10)		(3)(10)		
Isopogon ceratophyllus	1 3 10	1 3 10	1 3 10	(1) (3)(10)	1 3 10	(1) 3 10
Lomatia ilicifolia		(1) (3)	(1) (3)(10)		(1) (3)	
Persoonia juniperinum		(1) (3)(10)		1 3 10	1 3 10	1 3 10
Rutaceae						
Correa reflexa			(1) (3)(10)			
Casuarinaceae						
Allocasuarina pusilla	1 3 10	(1) (3)	1 3 10	(1) (3)(10)		1 3 10
Polygalaceae						
Comesperma ericinum						(1) 3

Table 1 continued next page (see legend on page 131)

Site Subsite Vegetation formation	A A_1 Closed heath	 A_2 Open scrub	 A_3 Tall shrubland	B B_1 Woodland	 B_2 Woodland	 B_3 Woodland/ closed scrub
Shrubs** (*continued*)						
Rhamnaceae						
Cryptandra tomentosa	(1) 3 (10)		(1) 3 (10)	(1) 3 10		
Spyridium parvifolium		(1) 3 (10)		10		
Spyridium vexilliferum	1 3 10	1 3 10	1 3 10			
Dilleniaceae						
Hibbertia prostrata				(1) (3)	1 3 10	1 3 10
Hibbertia sericea	10	(1) (3)	1 3	10		
Hibbertia riparia	1 3 10	(1) 3 10	(1) 3 10	1 3 (10)		
Hibbertia stricta	1 3 10	(1) 3 10	(1) 3 10	1 3 (10)		
Sterculiaceae						
Lasiopetalum baueri		(10)	(1) (3)(10)			
Thomasia petalocalyx		(10)	1 (3)(10)			
Asteraceae						
Olearia erubescens					(1) (3)	
Olearia myrsinoides					(1) (3)	
Olearia ramulosa		(1) (3)				
Olearia teretifolia	1 3 10	1 3 (10)	1 3 10			
Thymelaeaceae						
Pimelea glauca		(3)				
Pimelea humilis	1 3 10	1 3 10	1 3 10	(1) (3)	1 3 10	1 3
Pimelea linifolia		(3)(10)				
Pimelea octophylla	(1) (3)	(1) (3)	(1) 3	(1) (3)		
Pimelea phylicoides	3 10	3				
Solanaceae						
Solanum laciniatum		(1) (3)				
Tremandraceae						
Tetratheca ciliata	1 3 10	(1) (3)(10)	3 10	(3)(10)	1 3 10	3 10
Herbs**						
Rosaceae						
Acaena novae-zelandiae		(1) (3)				
Asteraceae						
Brachyscome uliginosa	1 3 (10)	3 (10)	1 3			
Craspedia spp.		(1) (3)			(1) (3)	
Argentipallium obtusifolium	(1) (3)	(1) (3)	(1) 3	(10)	(3)	(1) 3
Helichrysum scorpioides		(3)		3 (10)	(3)	3
Ixodia achillaeoides		(1) 3				
Lagenifera gracilis				1		(1)
Leptorhynchos squamatus		(1)				
Euchiton sphaericus		(3)				
Euchiton involucratus		(3)				
Euchiton spp.		10				
Euphorbiaceae						
Amperea xiphoclada						1 3
Poranthera microphylla				10		1

Table 1 continued next page *(see legend on page 131)*

Site	A			B		
Subsite Vegetation formation	A_1 Closed heath	A_2 Open scrub	A_3 Tall shrubland	B_1 Woodland	B_2 Woodland	B_3 Woodland/ closed scrub
Herbs** (*continued*)						
Droseraceae						
Drosera peltata ssp. *auriculata*	1 3 10	3 10	1 3 10	1 3 10	1 3 10	1 3 10
Drosera glanduligera	1 3 (10)	3 10		(1) (3)(10)	1 3	
Drosera macrantha	1 3 10	(3) 10	3 10	1 3 10	1 10	10
Drosera peltata	1	3			1 3	1 3
Drosera pygmaea	1 3				10	1 3 10
Drosera whittakerii	1	3 10		1 10	1 3 10	1 3 10
Rubiaceae						
Galium binifolium						(3)
Galium gaudichaudii						(3)
Opercularia scabrida				3 10		
Opercularia varia	1 3 10	1 3 10	1 3 10	1 3 10	1 3	1 3 10
Haloragaceae						
Gonocarpus tetragynus	1 3 10	1 3 10	1 3 10	1 3 10	1 3 10	1 3 10
Gonocarpus micranthus						(3) 10
Goodeniaceae						
Goodenia geniculata	1 3 10	1 3 10	1 3 10	1 3 10		(3)(10)
Goodenia lanata		(1) (3)	10	1	1 3	1 3 10
Scaveola albida	(3)		(3)			
Umbelliferae						
Hydrocotyle callicarpa		(3)	1	1		(3)
Hydrocotyle sibthorpioides						(3)
Platysace heterophylla				1 3	1 3 10	1 3
Xanthosia pusilla	1 3 10	3	1 3 10	1 3 10	1 3 10	1 3 10
Xanthosia dissecta						(3)
Lobeliaceae						
Lobelia gibbosa					(1)	(1) (3)
Lobelia rhombifolia	10	(3)			(3)	
Loganiaceae						
Mitrasacme pilosa						(3) 10
Oxalidaceae						
Oxalis corniculata		(3)				
Plantaginaceae						
Plantago varia		(1) (3)				
Stackhousiaceae						
Stackhousia monogyna	(1)	(1) (3)				
Stylidiaceae						
Stylidium graminifolium	(1) 3				(1) 3	
Stylidium perpusillum					(10)	
Violaceae						
Viola cleistogamoides	1 3 10	3 (10)	3 10			
Campanulaceae						
Wahlenbergia gracilenta	(1)	(1)		1 3		
Wahlenbergia stricta	(1)			1 10	1	
Polygalaceae						
Comesperma calymega	1 3	3	3	3	1 3	1 3 10
Geraniaceae						
Pelargonium australe	1			10		

Table 1 continued next page *(see legend on page 131)*

Site	A			B		
Subsite / Vegetation formation	A_1 Closed heath	A_2 Open scrub	A_3 Tall shrubland	B_1 Woodland	B_2 Woodland	B_3 Woodland/ closed scrub
Herbs** (*continued*)						
Brunoniaceae						
Brunonia australis		(1)			(1)	
Creepers and climbers**						
Pittosporaccae						
Billardiera scandens		(1) 3	1 3			1 3 10
Lauraceae						
Cassytha glabella	1 (3) 10	1 3 (10)	1 3 10	3 10	1 3 10	3 10
Cassytha melantha		(3)(10)				
Polygalaceae						
Comesperma volubile	1 3 10					
Fabaceae						
Kennedia prostrata	1	(1) 3 10			3	
Seedlings						
Monocotyledon	1	1	1	1	1	1
Dicotyledon	1	1 10	1	1	1	1
Sub-total vascular species in quadrats Year 1, Year 3, Year 10	64, 53, 43	38, 56, 42	49, 53, 46	42, 37, 38	38, 37, 29	40, 53, 39
Sub-total additional vascular species at site Year 1, Year 3, Year 10	31, 27, 8	51, 54, 26	19, 17, 10	24, 24, 14	42, 21, 5	24, 20, 15
Total vascular species† Year 1, Year 3, Year 10	95, 80, 51	89,110, 68	58, 70, 56	66, 61, 52	80, 58, 34	64, 73, 54
Sub-total non-vascular species in quadrats Year 1, Year 3, Year 10	1, 7, 16	2, 6, 13	0, 2, 7	0, 1, 6	0, 5, 8	0, 3, 9
Sub-total additional non-vascular species at site Year 1, Year 3, Year 10	0, 0, 7	0, 0, 5	0, 0, 3	0, 0, 0	0, 1, 0	0, 0, 0
Total non-vascular species† Year 1, Year 3, Year 10	1, 7, 23	2, 6, 18	0, 2, 10	0, 1, 6	0, 6, 8	0, 3, 9
Total species† Year 1, Year 3, Year 10	96, 87, 74	91,116, 86	68, 72, 66	66, 62, 58	80, 64, 42	64, 76, 56
Total species† Years 1–3 combined	115	137	86	78	99	84
Total species† Years 1–10 combined	136	159	100	86	103	96
Total species† Years 1–10 combined	260 species 221 species vascular plants 39 species non-vascular plants					

Table 1. Floristic comparisons between subsites 1, 3 and 10 years after fire. *Key:* 1 = present in quadrats year 1; 3 = present in quadrats year 3; 10 = present in quadrats year 10; (1) = present at site year 1; (3) = present at site year 3; (10) = present at site year 10; *11 × 12 m quadrats; **1 × 2 m quadrats; † = total species present in quadrats plus additional species present at site.

number of species of lichens present increased from 2 to 14 (Table 1).

In general, the number of non-vascular plant species increased with time since fire, while the number of vascular plant species decreased with time since fire (Tables 1, 3, Fig. 5).

Structure. The structure of the plant communities post-fire is presented in Table 2 and Figs 1–5. (In this paper the term 'shrub stratum' or understorey will also include the ground stratum.)

(a) E. obliqua *canopy recovery post-fire.* At all heath woodland sites, the rate of recovery of projective cover of the overstorey (relative to approximate pre-fire projective cover) accelerated between years 3 and 7 (Fig. 3). By year 7 the *E. obliqua* canopy of most heath woodland communities had reached both approximate pre-fire height and approximate pre-fire projective cover levels (Fig. 3).

Death of some basal, trunk and crown epicormic regrowth of *E. obliqua* occurred in all heath woodland communities as canopy recovery progressed (cf. profiles figs 3c, d, 4c, d of Wark et al. 1987; and Figs 1, 2 of this paper). In scrub, shrubland and woodland, whole epicormics died between 3 and 7 years, possibly from water stress or *P. cinnamomi* infection. In scrub and shrubland, shedding and death of large basal and trunk epicormics were often observed between 3 and 7 years. In these coastal communities, at least twice between 3 and 7 years, young regrowth tips on the seaward side of *E. obliqua* were killed by what appeared to be chloride toxicity from salt-laden winds.

(b) Shrub stratum (understorey) recovery post-fire. By year 7, the projective cover of the shrub stratum of all coastal (site A) subcommunities had reached approximate pre-fire levels (Table 2); in contrast, height of the shrub stratum in exposed locations had reached only 70–80% of the approximate pre-fire levels by year 7, and remained at about this level till year 10 (Table 2).

Subsite Vegetation type	A_1 Closed heath	A_2 Open scrub	A_3 Tall shrubland	B_1 Woodland	B_2 Woodland	B_3 Woodland/ closed scrub
Eucalypts (species)	–	EO**	EO	EO	EO	EO
Cover (%)						
Pre-fire (approx.)	–	30–70	10–30	10–30	10–30	10–30
3 years	–	20	20	20	20	20
7 years	–	70	30	30	30	30
10 years	–	70	30	30	30	30
Height (m)						
Pre-fire (approx.)	–	4.4	2.5	11.7	11.8	10.4
Live stem height after fire (year 0)	–	3.0	0.4	8.5	9.0	7.5
3 years	–	3.7	2.2	10.7	10.3	8.7
7 years	–	3.5	3.0	11.0	11.0	9.0
10 years	–	4.3	3.5	11.1	11.1	9.4
Understorey						
Cover (%)						
Pre-fire (approx.) all plants	70–100	30–70	30–70	30–70	30–70	30–70
3 years	64	61	57	20	75	92
7 years	92	75	76	37	78	76
10 years all plants	98	78	81	57	70	88
Height (m)						
Pre-fire (approx.)	0.5	1.0	0.5	0.5	1.5	1.5
Live stem height after fire (year 0)	0.0	0.0	0.0	0.0	0.0	0.0
3 years	0.2	0.2	0.2	0.2	1.0	0.8
7 years	0.35	1.0	0.31	0.7	1.0	1.0
10 years	0.35	1.0	0.35	0.8	1.1	1.2

Table 2. Structure of plant communities 3, 7 and 10 years after fire. *Tallest stratum; **EO = *Eucalyptus obliqua*.

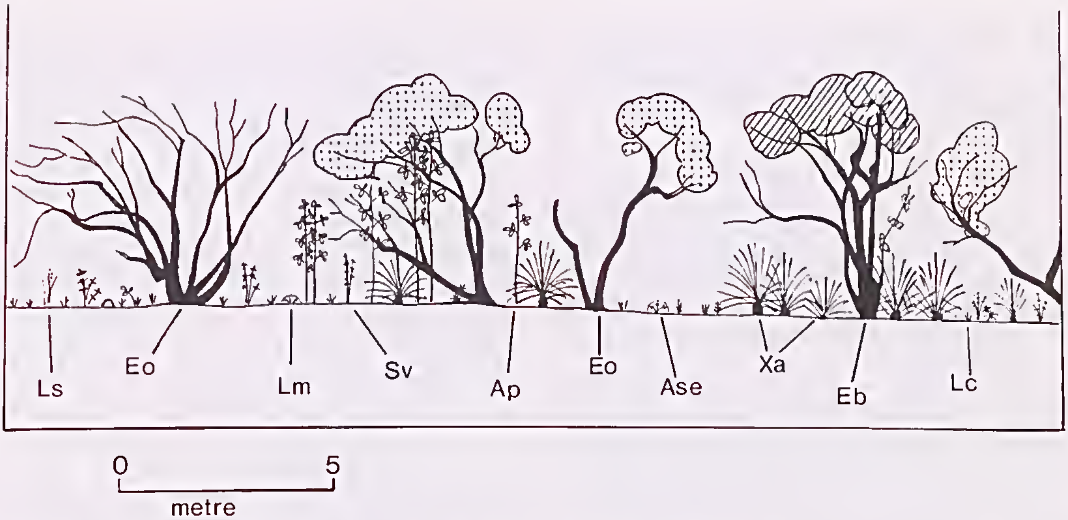

Fig. 1. Vegetation profile in open scrub (subsite A_2) 10 years after fire. Horizontal and vertical axes are the same. Stippling and hatching indicates the extent of canopy regrowth. (Profiles immediately after fire and at 3 years are shown in Wark et al. 1987—fig. 3c, d.) Eo = *Eucalyptus obliqua*, Eb = *Eucalyptus baxteri*, Xa = *Xanthorrhoea australis*, Ls = *Lepidosperma semiteres*, Ac = *Acacia pycnantha*, Ase = *Acrotriche serrulata*, Lm = *Leptospermum myrsinoides*, Sv = *Spyridium vexilliferum*, Lc = *Lepidosperma concavum*.

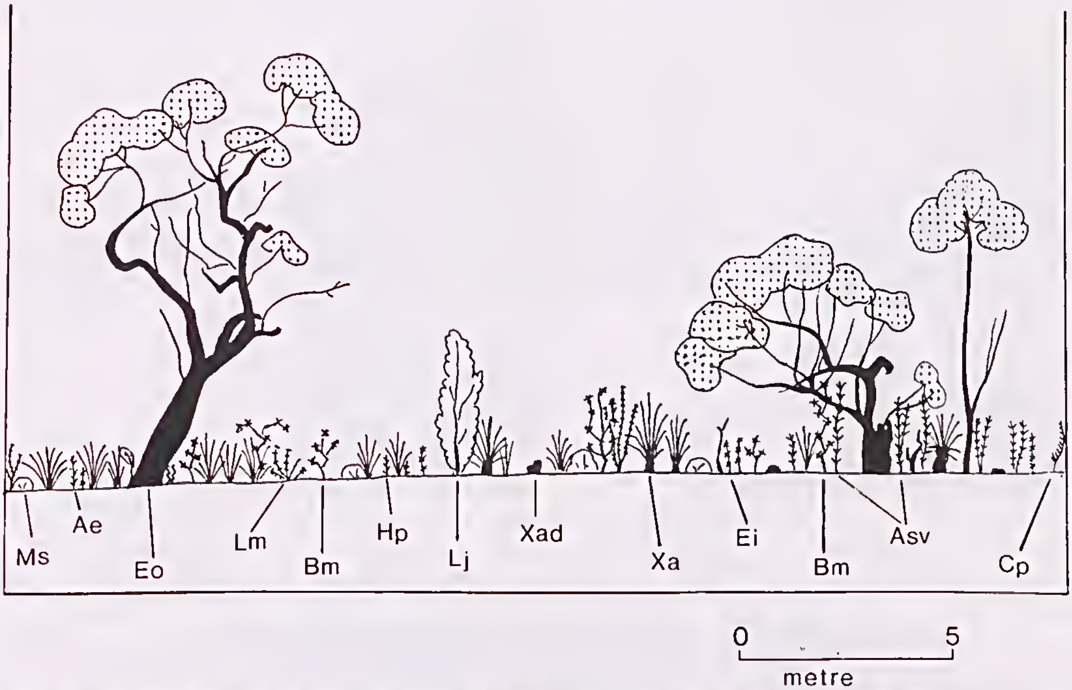

Fig. 2. Vegetation profile in woodland (subsite B_2) 10 years after fire. (Profiles immediately after fire and at 3 years are shown in Wark et al. 1987—fig. 4c, d.) Eo = *Eucalyptus obliqua*, Xa = *Xanthorrhoea australis*, Xad = dead *Xanthorrhoea australis*, Lm = *Leptospermum myrsinoides*, Bm = *Banksia marginata*, Ms = *Monotoca scoparia*, Ei = *Epacris impressa*, Ae = *Aotus ericoides*, Hp = *Hibbertia prostrata*, Lj = *Leptospermum continentalis*, Asv = *Acacia suaveolens*, Cp = *Allocasuarina pusilla*.

At site B, shrub stratum height had reached 91% of its approximate pre-fire level by year 7 (Table 2), and by year 10 both height and projective cover had reached approximate pre-fire levels (Table 2).

(c) Cover of shrub stratum 1–10 years post-fire. In both closed heath and heath woodland, cover of all herbs in the shrub stratum (other than sedges, rushes and *X. australis*) never exceeded 1% during the ten years post-fire. Shrubs were the major component of both closed heath, and the heath woodland understorey from year 3 onwards (Fig. 4).

A litter layer, composed of canopy-derived material (including shed branches and dead epicormic regrowth), plus shrub layer litter (including plants possibly killed by competition, water stress or *P. cinnamomi*) developed in the heath woodlands from year 3 onwards (Fig. 4). Where signs of *P. cinnamomi* dieback were seen, dead plants of *X. australis* and dead sclerophyllous shrubs were often a major component of the litter layer (cf. profiles fig. 4c, d, Wark et al. 1987; and Fig. 2 of this paper).

(d) Vascular plant cover and species richness 1–10 years post-fire. In both closed heath and heath woodland, the total number of species of vascular plants (in quadrats) decreased, and the total number of species of non-vascular plants (n quadrats) decreased as the combined percentage cover of the canopy and understorey increased (Fig. 5; Tables 1–3).

Bryophyte cover on the soil surface increased 3–10 years post-fire as the percentage of bare ground decreased and shrub cover increased. By year 10, bryophyte cover was 5% and 2% of total substratum cover in closed heath and heath woodlands respectively (Fig. 4).

Regeneration strategies

Approximately 70% of all species present at 1–3 years post-fire, and still remaining 10 years post-fire, had regenerated vegetatively after fire (Table 3). Half of the shrubs regenerating post-fire were sprouters and regenerated from lignotubers or rootstocks (Tables 1, 3; Wark et al. 1987, table 4). The other half of the shrubs established

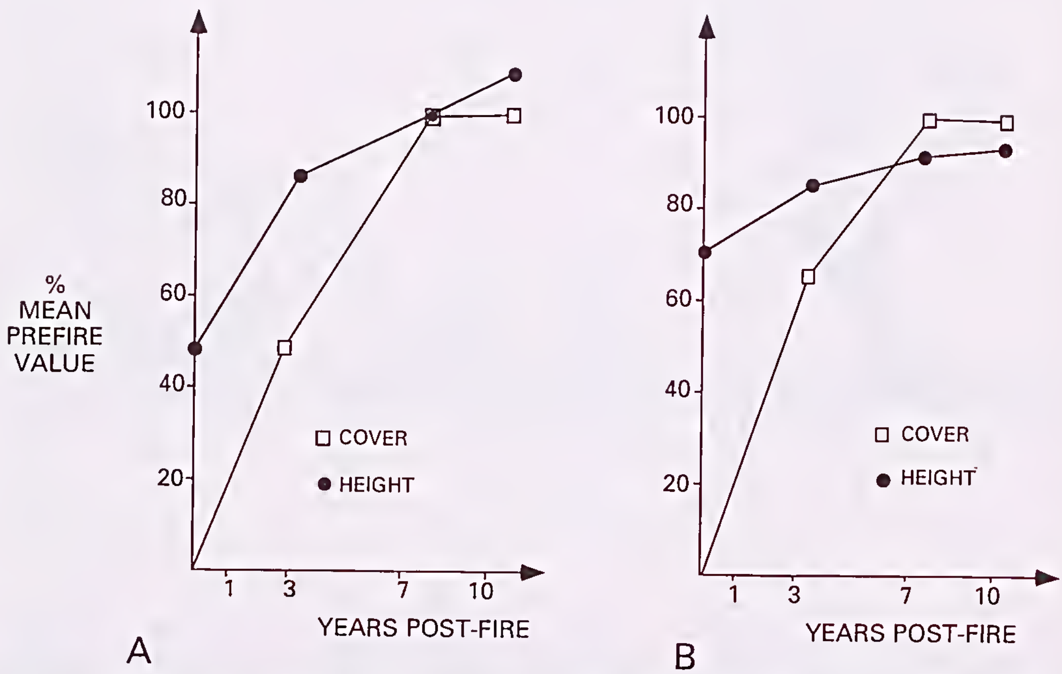

Fig. 3. *Eucalyptus obliqua* canopy recovery in heath woodland communities years 1–10 post-fire. A, Site A, subsites A_2 and A_3 combined. B, Site B, subsites B_1, B_2 and B_3 combined.

from seed, 1–2 years post-fire. By year 10, 51% of FRR shrubs remained compared with 44% of OSR shrubs. Seven of the 10 species of shrubs present at all sites at years 1, 3, 7 and 10 were FRR species (*A. serrulata*, *L. virgatus*, *L. myrsinoides*, *M. scoparia*, *P. obtusangulum*, *B. marginata* and *I. ceratophyllus*).

Ninety-eight per cent of the monocotyledonous herb species appearing post-fire were also sprouters (72% ORR and 26% FRR). ORR species included all sedges and rushes, all orchids and most lilies and irises. FRR species included 87% of grasses, the lilies *X. australis* and *X. minor*, and the irises *Patersonia fragilis* and *P. occidentalis*. Regrowth of both ORR and FRR species was by sprouting from rhizomes, stolons, corms or tubers.

Half of the dicotyledonous herb species appearing post-fire were ORR or FRR sprouters and the other half obligate seed regenerators. In both cases, less than half these species survived till year 10.

Few obligate seed regenerators became major components of the shrub (or tall shrub) stratum by year 10. Exceptions were *Acacia pycnantha*, *Olearia teretifolia* and *Spyridium vexilliferum* at site A; and *Acacia myrtifolia*, *A. suaveolens*, *A. verticillata*, *Spyridium parvifolium* and *Sprengelia incarnata* at site B.

Few seedlings of tree, shrub or herbaceous species were observed 7 and 10 years post-fire. The massive seedling germination seen in the first two years post-fire never recurred in later years. Seedling densities decreased as the amount of bare ground decreased (Fig. 6). By year 10, seedling densities of *Spyridium vexilliferum* and *Epacris impressa* in closed heath had reduced to <0.1% of the year 1 level (132/m^2, 138/m^2—Wark et al. 1987), and only 1–2 mature plants survived per m^2.

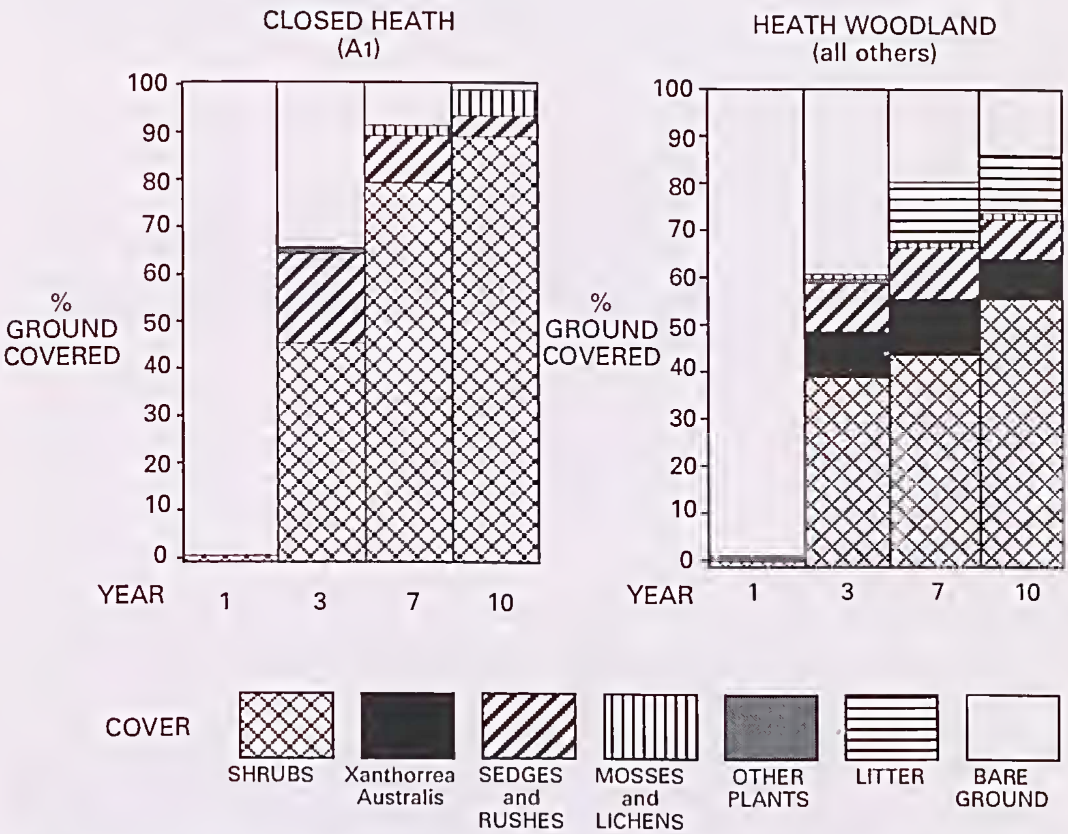

Fig. 4. Projective cover of shrub stratum in closed heath and heath woodland communities 1, 3, 7 and 10 years post-fire (closed heath = subsite A_1; heath woodland = subsites A_2, A_3, B_1, B_2 and B_3 combined).

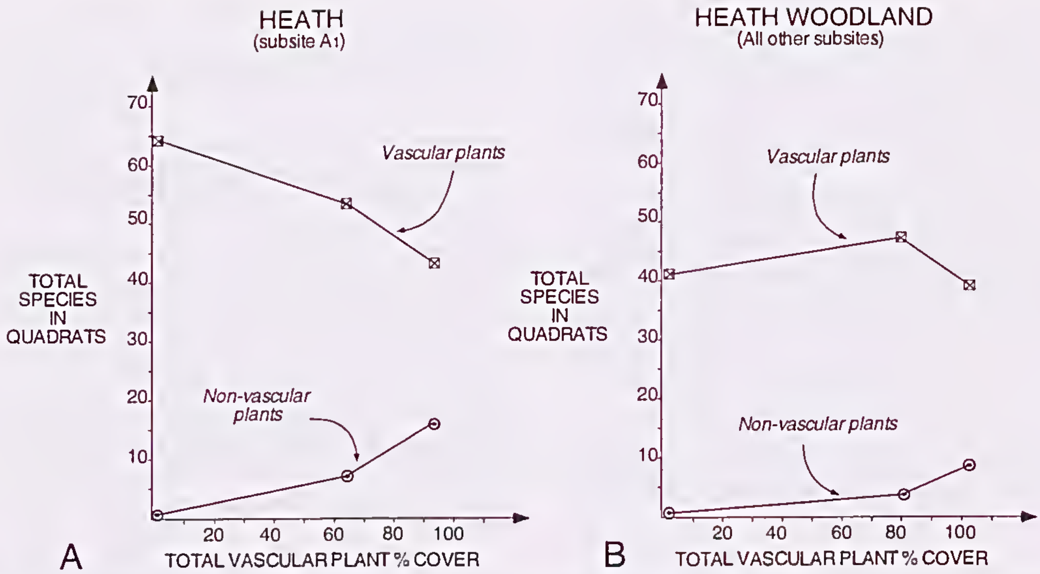

Fig. 5. Relationship of species richness to total vascular plant % cover. A, Closed heath = subsite A_1. B, Heath woodland = subsites A_2, A_3, B_1, B_2 and B_3 combined. *Note:* Heath woodland 'total vascular plant % cover' = total canopy and total understorey vascular plant % cover *combined*, minus litter layer cover.

Species present Regeneration strategy post fire	Years 1–3 OSR	 FRR	 ORR	Year 10 OSR	 FRR	 ORR
Trees (6)*	—	6	—	—	6	—
Shrubs (63)	32	31	—	21	27	—
Dicotyledon herbs (46)	23	12	11	13	4	7
Monocotyledon herbs (95)						
Orchids (36)	—	—	36	—	—	18
Lilies and irises (19)	—	4	15	—	2	6
Grasses (23)	3	20	—	—	5	—
Sedges and rushes (17)	—	—	17	—	—	10
Creepers and climbers (5)	5	—	—	5	—	—
Ferns (6)	—	2	4	—	1	1
Non-vascular plants (10)†	10	—	—	5	—	—
Sub-total	73	75	83	44	45	42
Total species‡ (%)	32	32	36	34	34	32
Total species‡†		231			131	

Table 3. Regeneration strategies and life form groups of all species appearing 1–3 years post fire, and still present 10 years post fire. *Key:* OSR = obligate seed regenerators; FRR = facultative regrowth regenerators; ORR = obligate regrowth regenerators. Terminology follows Purdie (1977a, b). *Note:* *Numbers in brackets show total species present years 1–3; †29 species (mosses, lichens, liverworts, algae) which appeared after year 3, and were present at year 10, have not been included in these data; ‡Total species = total number of species recorded (quadrat and site data combined).

When young *E. impressa* seedlings were found at year 10, these were always in open areas (e.g. along access tracks near the study sites, where there was probably less competition for light, moisture and nutrients).

Seedling densities of *Eucalyptus obliqua* in closed heath remained unchanged at 5/ha between years 3 and 10 post-fire (5/ha—years 3 and 10). In contrast, year 10 *E. obliqua* seedling densities in open scrub were 1% of the year 3 level (>1000/ha year 3, cf. <10/ha year 10).

Flowering response after fire

The frequency of flowering of orchids decreased between years 1 and 10. Only 50% of the 34 species of orchids which appeared and flowered at year 1 were both present and flowered at year 10 (Table 1). A similar reduction occurred in the number of species of lilies and irises flowering at year 10 (42% of year 1 level).

All species of eucalypts and shrubs which had not flowered and set seed by year 3 flowered and set seed by year 7. Shrubs included the obligate seeder *Hakea ulicina*.

DISCUSSION AND CONCLUSIONS

Species richness post-fire

The species richness of vascular plants in heath and heath woodland decreased with time post-fire, as reported for other heath and heath woodland communities in Australia (Specht et al. 1958; Russell & Parsons 1978; Posamentier et al. 1981; Specht 1981; Bell et al. 1984; McFarland 1988; Specht 1994).

There was both a floristic change and an increase in the number of species of non-vascular plants with time. The early post-fire moss and liverwort colonisers (*Funaria hygrometrica*, *Marchantia berteroana*) appeared in the first year, as part of a succession (Wark et al. 1987) and were not seen after 3 years. Similar observations have been made by Cremer and Mount (1965) and Duncan & Dalton (1982) in Australian sclerophyll forests. With the exception of *F. hygrometrica* (Southorn 1976, 1977), the factors which promote post-fire colonisation of dry sclerophyll forests by bryophytes are not well understood (Warcup 1981). In the present study, the number of species of non-vascular plants present increased as vascular plant cover increased. Two species were observed at year 1; by year 3 (when understorey total plant cover was 60–65% of pre-fire) an additional 7 species (mainly mosses) had been recorded; and by year 10 (when understorey total plant cover was 87–98% of pre-fire) an additional 29 species (mainly lichens) were found. It is probable that several species of lichens were present earlier, but because of their slow growth rate were not recognised. Most of the lichens identified at year 10 were decay species. Most of the liverworts identified at year 10 were ground or wood species which require some shade and moisture; their presence may indicate changed climatic and edaphic conditions in the ground stratum by year 10.

Vegetation structure post-fire

It was observed from year 3 onwards that, as canopy cover of the overstorey increased, species richness of the heathy substratum declined and shrubs became increasingly dominant, as reported for other heath woodlands in Australia (Specht et al. 1958; Russell & Parsons 1977; Specht & Specht 1989).

The rate of recovery of canopy height and cover was faster than that of the substratum, as reported for other heath woodlands in southern Australia (Specht & Morgan 1981). Canopy recovery may be influenced by a variety of factors such as the presence of *P. cinnamomi*, moisture stress, or exposure to salt wind. Canopy dieback has already been reported for the Anglesea area (Weste 1975) and death of regenerating *E. obliqua* canopy at sites A and B, between 3 and 7 years post-fire, could have been caused by *P. cinnamomi* which was isolated from soil at both sites. In early years post-fire, damage observed on both canopy and heathy understorey at site A was probably caused by salt spray (Wark et al. 1987). Similar effects have been described by Parsons and Gill (1968) and Parsons (1979) for other coastal heathlands in Australia, and may explain the slow recovery of height of the open scrub canopy and the closed heath substratum at Point Addis.

The post-fire regeneration strategies of the Anglesea heaths and heath woodland communities conform to the 'initial floristic composition' regeneration model (Egler 1954; Purdie & Slatyer 1976). All species of vascular plants known to be present prior to the fire re-established during the first three years post-fire (White 1982; Wark et al. 1987) and no additional species appeared between 3 and 10 years post-fire.

Vegetative regrowth is the main regeneration strategy after fire in the Anglesea heaths and heath woodlands (Wark et al. 1987). Seventy per cent of all species that survived the first 10 years post-fire were either FRS or ORS sprouters as reported for other heaths and dry sclerophyll woodlands in southern Australia (Gill & Groves 1979; Specht 1981). Most sprouting species appeared before those which regenerated from seed, with the competitive advantage of established root systems, in areas of limited water, nutrients or light.

Seedling mortality was high in the early years post-fire (Wark et al. 1987; present study) and few seedlings established once regrowth commenced; this same pattern was recorded for Dark Island heath South Australia (Specht et al. 1958). Both Specht (1981) and Gill (1981) have observed that seedling regeneration in southern Australian heaths was restricted to the immediate post-fire period. In the present study, it was noted that once regrowth of sprouting species became vigorous, there was high mortality of seedlings which had established in gaps. Competition for space, water, nutrients and light all probably contributed to this increased mortality.

Some obligate seeders (e.g. *Hakea ulicina*) did not set seed in the first 3 years after fire, and it was suggested that burning of the heaths and heath woodlands within the first 3 years could result in elimination of such species (Wark et al. 1987). Coaldrake (1951) observed elimination of the OSR shrub *Banksia ornata* from South Australian heaths burnt twice within 3 years, and Gill and McMahon (1986) estimated that a 16 year fire-free interval could be needed to achieve stand replacement of this fire-sensitive species.

In the present study, it was observed that all obligate seeders had set seed by year 7 post-fire. It could be assumed that burning of the Anglesea heaths and heath woodlands 7 years or more after fire would probably not eliminate OSR regenerators such as *H. ulicina*. However, recent demographic studies in New South Wales on the OSR shrubs *Banksia ericifolia* and *Petrophile pulchella* show that freedom from fire during the primary juvenile period is only one of several factors which influence successful establishment of fire-sensitive OSR species (Bradstock & O'Connell 1988).

The success of seedling establishment (which may be affected by climate, predation, or rate of seed release post-fire), the size of the pre-fire seed bank and the rate of survival of seedlings, juveniles and adults, may also influence post-fire survival of OSR species. Bradstock and O'Connell (1988) have shown that, although *B. ericifolia* sets seed 6 years post-fire, if seedling establishment rates are low post-fire, a fire-free interval of 13 years is required to ensure population replacement.

More information is needed on the life cycles and demographic behaviour of the fire-sensitive OSR species of the Anglesea–Airey's Inlet heaths and heath woodlands to assist in conservation management.

Flowering response post-fire

The spectacular post-fire flowering response of herbaceous species which occurred in the first year post-fire (Wark et al. 1987), was not seen in later years. Similar observations have been made by Gill (1981, 1993) and Specht (1981, 1994) for a range of heath woodlands in Australia. In the present study, species of the families Liliaceae and Orchidaceae appeared, but often did not flower between 3 and 10 years post-fire. The lack of flowering may be due to lack of light or moisture, or to the absence of a fire stimulus such as the presence of extra nutrients which accumulate in ash, or originate from the humus layer.

Phytophthora cinnamomi

Phytophthora cinnamomi was isolated from the Anglesea area in 1973 prior to the fire, and from all sites 3 years after the 1983 fire. The early isolations in this area (by Dr G. Marks) were from sites as widespread as the Iron Bark Basin Reserve, Point Addis; the Ocean Road Flora Reserve, Anglesea; and the Angahook State Park, Airey's Inlet (Weste & Marks 1974; Weste 1975; Pittaway 1976).

It appears that *P. cinnamomi* disease may have been present at most of the subsites prior to the 1983 wildfire. Symptoms and mortalities in susceptible species indicated disease extension from all subsites during the first decade after fire. Species were replaced by resistant sedges and rushes, which may act as temporary reservoirs of infection (Phillips & Weste 1984).

It is possible that *P. cinnamomi* disease is modifying the vegetation floristics of the Anglesea area. In the Brisbane Ranges, Grampians and Wilson's Promontory National Parks, *P. cinnamomi* dieback has resulted in the transformation of a species-rich heath woodland community to a sedge-woodland containing few species (Weste & Taylor 1971; Weste & Law 1973; Weste 1981, 1986; Kennedy & Weste 1986). Such changes have been observed in the Ocean Road Flora Reserve, east of Anglesea, where *P. cinnamomi* has modified the floristics and caused changes in cover and local reduction in species richness (Weste & Marks 1974; Weste 1975). Similar changes may be occurring at site B in the present study (Wark et al. 1987), in the coastal heath and heath woodlands west of Anglesea (Carr et al. 1991), in the Angahook–Lorne State Park (Carr et al. 1995a) and in the heath woodlands of the Alcoa leasehold north of Anglesea (Meredith 1986; Cameron & Downe 1994; Carr et al. 1995b).

A recent study of vegetation changes associated with *P. cinnamomi* invasion in the Grampians National Park has produced quantitative evidence that *P. cinnamomi* disease may threaten the survival of rare, susceptible endemic species (Kennedy & Weste 1986) . The distribution of the pathogen in the Anglesea area is currently patchy (G. Weste, pers. comm.), however wider spread could threaten local endemics such as *Grevillea infecunda*, which only occurs in a few scattered patches near Anglesea. This is an obligate resprouter (Wark et al. 1987) which never reproduces from seed (McGillvray 1993). *P. cinnamomi* disease could result in its elimination. *Conospermum mitchelli* and *Hakea repullulans* are two other ORR shrubs which though not endemic could be threatened by *P. cinnamomi* disease spread. Investigations are needed to determine whether these 3 species are susceptible and whether they grow in areas currently or likely to become infested. The latter can only be determined when the precise distribution of *P. cinnamomi* in the Anglesea area is known.

Management practices are required to control *P. cinnamomi* disease spread in the Anglesea–Airey's Inlet region, particularly with regard to road construction, the use of infested gravel, and the cleaning of road vehicles.

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	Authority	
	Forbes (1984) etc.*	Ross (1993) etc.†
Trees	*Eucalyptus sideroxylon*	*Eucalyptus tricarpa*
Tall shrubs	*Casuarina stricta*	*Allocasuarina verticillata*
Sedges and rushes	*Caustis restiaceae*	*Caustis flexuosa*
Grasses	*Danthonia caespitosa*	*Rytidosperma caespitosum*
	Danthonia geniculata	*Rytidosperma geniculatum*
	Danthonia induta	*Rytidosperma indutum*
	Danthonia pilosa	*Rytidosperma pilosum*
	Danthonia procera	*Rytidosperma procerum*
	Danthonia semiannularis	*Rytidosperma semiannularis*
	Danthonia setacea	*Rytidosperma setacum*
	Danthonia tenuoir	*Rytidosperma tenuis*
	Themeda australis	*Themeda triandra*
Orchids	*Acianthus exertus*	*Acianthus pusillus*
	Caladenia menziesii	*Leptocerus menziesii*
	Caladenia dilatata	*Caladenia tentaculata*
	Diuris longifolia	*Diuris corymbosa*
	Lyperanthus nigricans	*Pyrorchis nigricans*
	Prasophyllum despectans	*Genoplesium despectans*
	Prasophyllum morisii	*Genoplesium morrisii*
	Pterostylis vittata	*Pterostylis sanguinea*
	Thelymitra fusco-lutea	*Thelymitra benthamiana*
Lilies and irises	*Dichopogon strictum*	*Arthropodium strictum*
	Laxmannia sessiliflora	*Laxmannia orientalis*
Shrubs	*Leptospermum juniperinum*	*Leptospermum continentale*
	Casuarina pusilla	*Allocasuarina pusilla*
	Hibbertia stricta	*Hibbertia stricta*
		Hibbertia riparia
Herbs	*Acaena anserinifolia*	*Acaena novae-zelandiae*
	Brachycome uliginosa	*Brachyscome uliginosa*
	Craspedia glauca	*Craspedia* spp.
	Helichrysum obtusifolium	*Argentipallium obtusifolium*
	Gnaphalium sphaericum	*Euchiton sphaericus*
	Gnaphalium involucratum	*Euchiton involucratus*
	Gnaphalium spp.	*Euchiton* spp.
	Drosera auriculata	*Drosera peltata* ssp. *auriculata*
	Scaevola pallida	*Scaevola albida*

Appendix. Nomenclature of vascular plants—name changes since the first paper in this series. *Forbes (1984) and other authorities listed in Wark et al. (1987); †Ross (1993) and other authorities listed in the present paper.